LECTURE #2: ELECTRIC AND MAGNETIC FIELDS

The study of electric and magnetic fields bridges the areas of circuit theory, transmission lines, and radio and microwave systems. It is the foundation of electrical engineering.

In circuit design, we use lumped parameter modeling of components and effects. But really, we are modeling the fields within and on the periphery of the circuit. Of course when we talk about electromagnetic compatibility or electromagnetic interference, the field effect about the circuit becomes of great importance.

Transmission lines with spaced conductors actually have most of the signal energy in the area between and outside of the conductors. Of course this leads to the efficient design of antennas or other radiating systems.

ELECTRIC FIELDS

The basic electric quantity is charge Q. This is an isolated charge surrounded by an electric field that exerts force on all other charges in space. So if we have two charges in space separated by a distance r in the direction defined by the unit vector $\hat{\mathbf{r}}$, then the force exerted on the charge Q_2 from Q_1 is given by Coulomb's law:

$$\mathbf{F} = F\hat{\mathbf{r}} = \frac{Q_1 Q_2}{4\pi\varepsilon r^2}\hat{\mathbf{r}} \quad [\text{N}]$$

The permittivity of the dielectric material ε is the product of the dimensionless relative permittivity ε_r multiplied by the permitivity of vacuum ε_o :

$\varepsilon = \varepsilon_r \varepsilon_o$ where $\varepsilon_o = 400\pi$ [nH/m] .

The force per unit charge is called the *Electric Field*:

$$\mathbf{E} = \frac{\mathbf{F}}{Q_2} = \frac{Q_1}{4\pi\varepsilon r^2}\hat{\mathbf{r}} \quad [\text{V/m}] \ .$$

LINE CHARGES